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Baltimore Demonstrates Gas Pyrolysis. The Energy Recovery Solid Waste Facility in Baltimore, Maryland

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a current report
on solid waste management

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BALTIMORE DEMONSTRATES GAS PYROLYSIS

THE ENERGY RECOVERY SOLID WASTE FACILITY IN BALTIMORE, MARYLAND

The first Interim report (sw-75d.i) on work performed under Federal solid waste management demonstration grant No. S-801533 to the City of Baltimore was written by David B. Sussman.

U.S. ENVIRONMENTAL PROTECTION AGENCY
1974

This report has been reviewed by the U.S. Environmental Protection Agency. Its publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. Government.

An environmental protection publication (SW-75d.i) in the solid waste management series.

FOREWORD

Growing concern for the environment has changed our thinking about solid waste. Although disguised as a nuisance, solid waste can be an environmental asset. It contains a wealth of recyclable materials--paper, cardboard, metals, and glass and offers the potential for conserving a seriously diminishing resource--fossil fuels.

In this period of concern about shortages of energy and material resources, the mere existence of untapped resources commands our attention. Recycling and reuse of waste materials makes good sense environmentally and economically. Information is emerging to show that recovering and reusing our resources is sound practice for more reasons than those that are obvious. For example, when two production systems are compared, one using virgin materials, the other secondary or waste materials, the system using wastes almost always causes less air and water pollution, generates less solid wastes, and consumes less energy. This is true if the environmental impacts of all activities in a system are measured--mining, processing, fabrication, manufacturing, and the transportation and disposal steps in between.

The Nation's task, then, is to organize our systems and institutions so that the economy can begin to receive the benefits and reflect the savings from using more secondary materials. One way to help accomplish this is through new technology. But technological advances are usually expensive, are relatively untried, and therefore entail some risk. The Resource Recovery Act of 1970 enabled the Federal solid waste management program to assist States and municipalities by assuming part of the risk of trying new technologies. The result was a significant expansion of the Federal resource recovery demonstration program. This report describes one part of that program: the recovery of energy in the form of steam by converting solid waste into a combustible gas through a pyrolytic process, and then using the gas as a fuel to fire a steam boiler.

The pilot process was developed by Monsanto Enviro-Chem Systems, Inc., St. Louis, Missouri. In July 1972, the City of Baltimore applied for a grant to demonstrate the Monsanto "Landgard" system with a full scale pyrolysis plant. The concept presented by the City looked encouraging. Consequently, the U. S. Environmental Protection Agency's Office of Solid Waste Management Programs awarded a grant to the City of Baltimore for 40 percent of the cost of the project.

Construction began in early 1973 and full-scale operation is scheduled in early 1975.

This demonstration exemplifies the kind of creative solutions that government at all levels, industry, and the public must pursue to bring our environmental and resource conservation problems under control.

Arsen J. Darnay
Deputy Assistant Administrator
for Solid Waste Management Programs

BALTIMORE DEMONSTRATES GAS PYROLYSIS

THE ENERGY RECOVERY SOLID WASTE FACILITY IN BALTIMORE, MARYLAND

Converting municipal solid waste into energy is a solid waste management option that has recently become attractive, both environmentally and economically. Although a number of European countries have been generating steam and electricity from municipal solid waste for years, recovery of energy from municipal solid waste has been limited in the United States. Until recently, it consisted of relatively inefficient waste-heat boilers installed in conventional incinerators. In the past five years, however, more sophisticated solid waste incinerators have been built, which incorporate boilers for the recovery of steam.

But these newer facilities, known as waterwall incinerators, have several important limitations. First, the ability of these incinerators to meet and maintain clean air standards economically is questionable. Pollution control of incinerators is expensive and technically difficult. Secondly, new facilities are relatively expensive both in capital and operating cost. Third, their relative reliability has not always been acceptable. Fourth, the energy conversion efficiency is somewhat less than desirable.

By converting solid waste into a new fuel and burning the fuel in a boiler, the above limitations can be reduced. While the pyrolytic conversion of solid waste into steam is not a panacea for either the solid waste problem or the energy crunch, it certainly can be a significant part of the solution to both. The concept was considered attractive enough for the City of Baltimore to undertake this innovative venture with financial support from the U. S. Environmental Protection Agency's Office of Solid Waste Management Programs. The project is scheduled to be processing waste in early 1975.

INTRODUCTION

Project Objectives

The primary objective of the project is to demonstrate the technical and economical feasibility of recovering energy from mixed municipal waste using a gaseous pyrolysis process. Pyrolysis is the physical and chemical decomposition of organic matter brought about by the action of heat in an oxygen-deficient atmosphere. In order to meet the objective, the City of Baltimore is building a full size 1,000 ton per

day plant that will receive mixed municipal solid waste, including white goods*, tires, and eventually sewage sludge**. The plant will generate steam, recover ferrous metals, and produce char and a glassy aggregate product. The project includes the design, construction, operation and evaluation of a system that will convert most of the input waste into useable products. It will receive approximately one half of Baltimore's residential solid waste.

The project also will evaluate the marketing of steam, ferrous metals and pyrolysis residues.

Benefits

The project has many potential benefits. The most important ones are: (1) the disposal of about one half of the residential solid waste of the City, without environmental degradation, (2) the energy recovered from the waste in the form of steam and the associated saving of fossil fuels, and (3) a disposal cost that is, based on preliminary economic analysis, less than landfilling and incineration.

Project Participants and Their Roles

EPA awarded $6 million toward the cost of the $16 million project. The Federal share was provided under the authority of Section 208 of the Solid Waste Disposal Act, as amended.

The Maryland Environmental Service (MES) provided the project with a $4 million loan. MES is an agency of the State Department of Natural Resources and has authority to finance projects that preserve, improve or manage state air, water, and land resources.

The City of Baltimore is providing the remaining $6 million for the pyrolysis plant, and the land on which the plant is sited. The loan from MES will be reimbursed from the proceeds received from the sale of the steam, glassy aggregate, and the ferrous metal.

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*White goods are refrigerators, washing machines, stoves, and other household items. The ability of the plant to accept these items (oversize bulky wastes) is a function of the shredder size and design, not of the pyrolytic process.

**Sewage sludge was pyrolyzed in the pilot plant successfully, and this concept may be further tested in the Baltimore project.

Monsanto Enviro-Chem Systems, Inc., of St. Louis Mo., developed the "Landgard"* system and operated a 35 ton per day pyrolysis pilot plant. Monsanto also designed and, through their subsidiary, the Leonard Construction Company, is building the 1,000 ton per day plant in Baltimore. Monsanto will turn over to the City a fully operational, demonstrated plant early in 1975.

Project Schedule

Construction is presently underway (Table 1). All development and pilot testing work has been completed by Monsanto. Although it is expected that the plant will operate as planned, one must be cautioned that the data presented in this paper are based on the experiences of the 35 ton per day pilot plant. The economics and recovery rates are projected from those data.

TABLE 1

MAJOR PROJECT MILESTONES

Groundbreaking	January 1973
Complete Design	January 1974
Complete Construction	October 1974
Plant Start-up	November 1974 - February 1975
Operation and Evaluation	February 1975 - February 1976

SYSTEM DESCRIPTION

Original Development Work

In 1967 Monsanto began a survey of solid waste problems and their future impact. The company, because of long experience in materials processing, decided to concentrate on disposal methods, and investigated various waste disposal ideas including pyrolysis. The study recognized resource recovery as an attractive tool in solid waste management and pyrolysis as the most attractive option. A study of pyrolysis processing systems determined that direct-fire pyrolysis using a rotary kiln would be the best method. A rotary kiln is a type of chamber that is cylindrical in shape, slightly inclined, and rotates about its

*"Landgard" is the name of a proprietary system of the Monsanto Enviro-Chem Systems, Inc. Apparatus and process patents have been allowed by the U. S. Patent Office for the System.

horizontal or lengthwise axis (item 4 in Figure 1). Solid waste enters the high end of the kiln. Rotation tumbles the material and allows for complete heating. Gravity slowly moves the material to the low end for discharge. Fuel is fired directly into the kiln (hence, the term direct-fired) rather than indirectly by heating the kiln's outer shell, as in a popcorn popper. Rotary kilns are used extensively in the cement industry and in processing many granulated materials. Monsanto has designed and operated several similar units.

After a laboratory model of a direct-fire continuous pyrolysis unit was built and operated in Dayton, Ohio, Monsanto decided to build a pilot-size pyrolysis unit to investigate scale up data for full-size plant design. Trial handling of mixed municipal solid waste began near Monsanto's St. Louis plant in June 1969.

Continuous operation at a feed rate of 35 tons per day was demonstrated by early 1970. The next year, a residue recovery system was added to recover carbon char, glassy aggregate, and ferrous metal. The pilot plant was dismantled in late 1971 after all testing work was completed.

The system being built in Baltimore is a scale-up of 35 to 1,000 from this pilot plant. Scale-ups of this ratio are common in both the petro-chemical and materials processing industries, and no major scale-up problems are expected.

Site Description

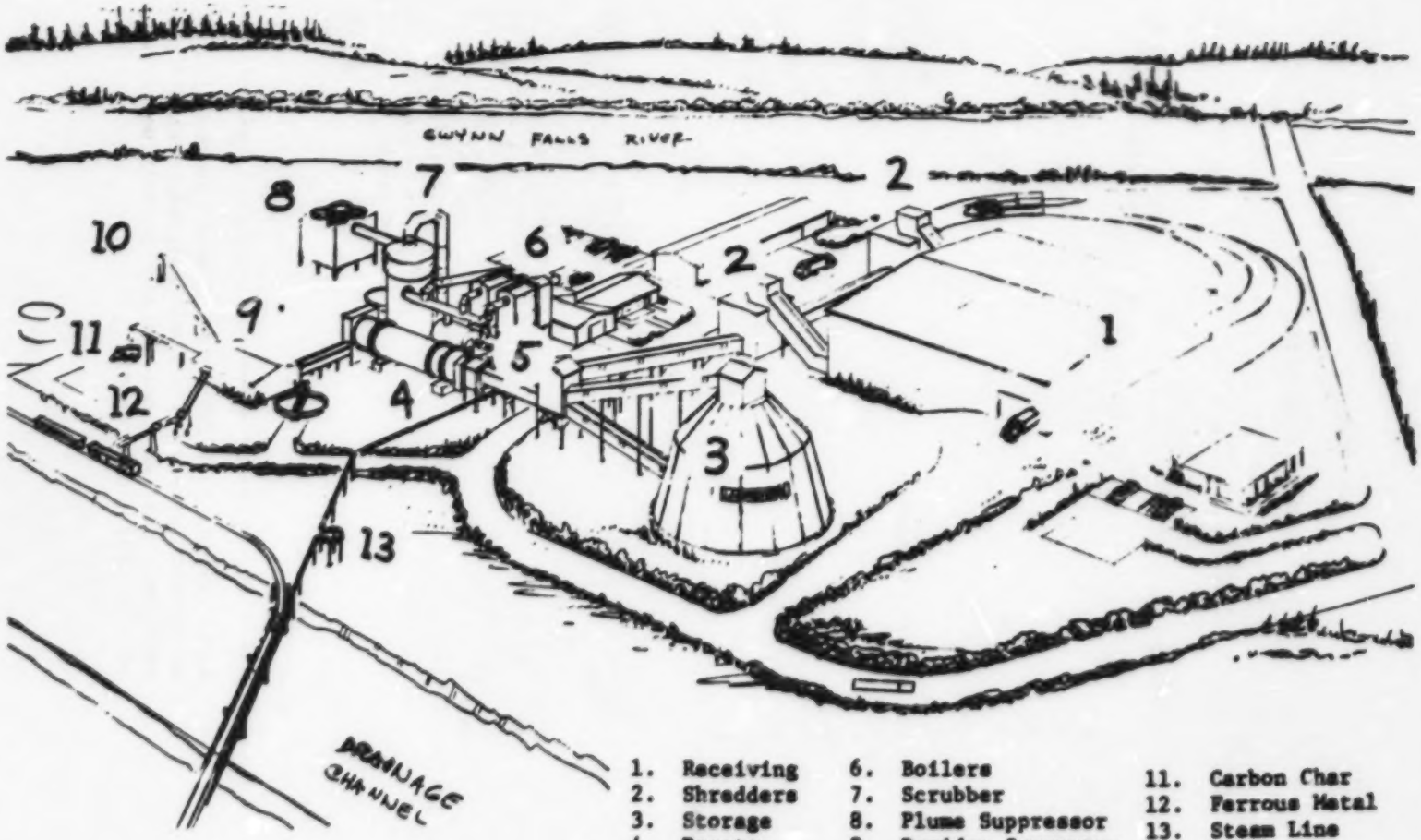
The plant is located on a 16 acre peninsula located just south of the Baltimore business district. The entire site is zoned industrial, and the use of the site for the pyrolysis plant is consistent with industrial redevelopment plans for the area.

Waste Types Processed

Residential and commercial solid wastes are processed. The composition of this waste is shown in Table 2.

FIGURE 1

BALTIMORE RESOURCE RECOVERY PLANT



1. Receiving
2. Shredders
3. Storage
4. Reactor
5. Afterburner
6. Boilers
7. Scrubber
8. Plume Suppressor
9. Residue Separator
10. Glassy Aggregate
11. Carbon Char
12. Ferrous Metal
13. Steam Line

TABLE 2

WASTE COMPOSITION

Kinds of Materials		Percent of Total (At Plant Input)
Paper		38
Glass		10
Metals		10*
Ferrous	8	
Aluminum	1*	
Other	1*	
Plastics		4
Rubber and Leather		3
Textiles		2
Wood		4
Food Wastes		14
Yard Wastes		14
Misc. Inorganics		1
		100

CHEMICAL ANALYSIS
(PERCENT)

Proximate Analysis (Pre-Pyrolysis)		Ultimate Analysis (Post-Pyrolysis)	
Moisture	21	Ferrous	7
Volatiles	45	Glass & Ash	19
Fixed Carbon	8	Water	21
Inerts	26	Carbon	25
	100	Sulfur & Nitrogen	1*
		Hydrogen	3
		Oxygen	24
			100

* Less than

Source: Waste Composition, EPA Data. Average composition of U.S. solid waste stream. Chemical Analysis, Monsanto pilot plant sampling. Data were not obtained in Baltimore, but are typical of U.S. urban solid waste.

The plant accepts residential and commercial solid waste typical to any American city. White goods, occasional tires and the like are processed; however, automobiles and industrial wastes are excluded. Oversized bulky or non-shreddable waste can be removed from the system before processing by the loader operators. Automatic safety devices will remove large, non-shreddable wastes or stop the conveyor belt, thereby preventing damage to the processing equipment. The flow through the plant is illustrated in Figure 2.

Capacity

The receiving and shredding system is designed to process 1,000 tons of solid waste a day working a 10 hour shift. The pyrolysis reactor, material recovery, and steam generator subsystems will operate continuously 24 hours per day, seven days per week. In order to feed the reactor continuously from this intermittent preparation stream, a 2,000 ton storage bin is provided.

Receiving Area

Raw solid waste is discharged from conventional collection vehicles into a concrete pit* in the receiving building. The collection trucks are weighed prior to and after dumping. Two bulldozers push the solid waste onto separate conveyors each leading to the shredders. The conveyors are located at the opposite ends of the receiving pit and elevate the waste from below floor level in the pit to the top of the shredders.

Shredders

Mixed municipal solid waste is a very heterogeneous commodity. However, most materials processes require a reasonably homogeneous feed. Shredding the waste homogenizes the material, reduces odors, and makes handling easier. The waste is fed into the two hammermill shredders. In these machines**, 30 large hammers swing on pins attached to the horizontal shaft and grind or mill the waste against steel grates until the waste is shredded into 4 inch particles that are small enough to fall through the grates. The milled refuse exits the bottom of the shredders onto a conveyor and proceeds to the storage bin or directly to the kiln.

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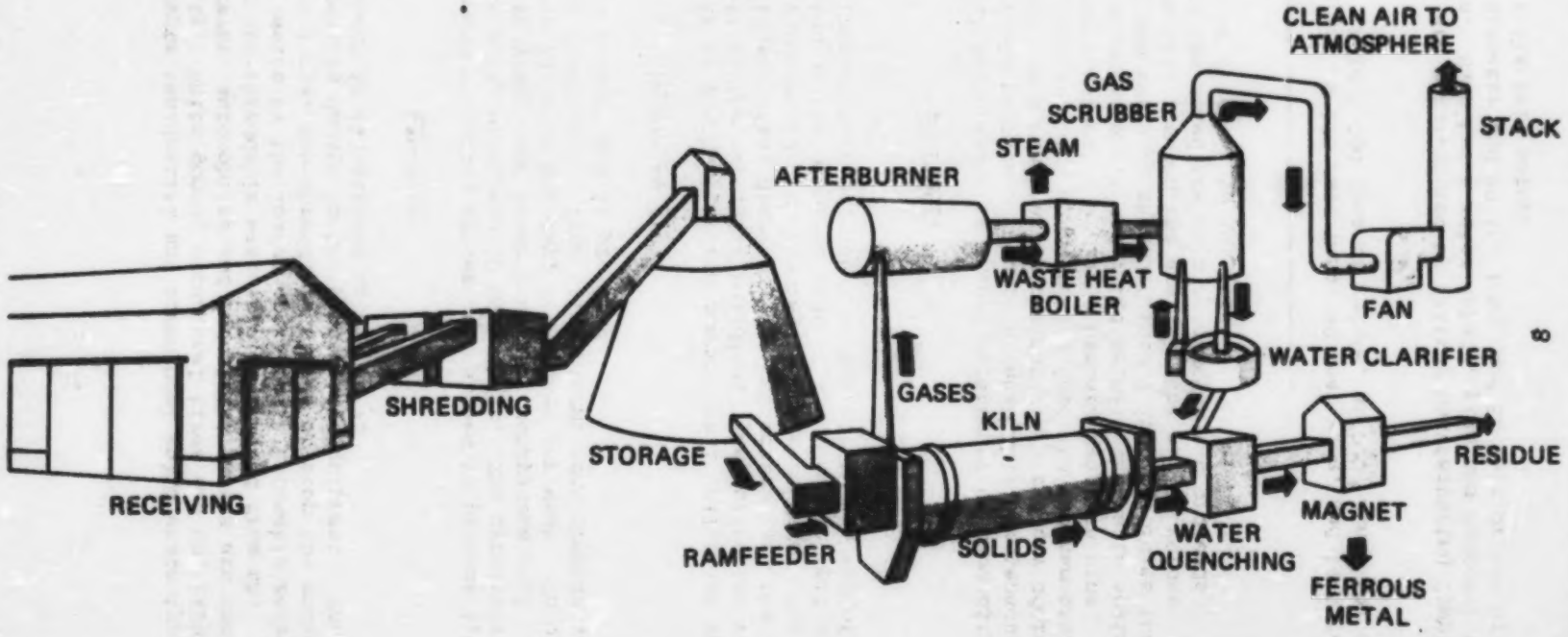
* The receiving pit is 160 feet long, 80 feet wide, and 14.5 feet deep, and will hold 1,000 tons of refuse, at 270 pounds per cubic yard density.

** The shredders are manufactured by Jeffrey Manufacturing Company, Columbus, Ohio. Each has a rotor (shaft, pins and hammers) that is 73 in. in diameter and 99 in. long, and is belt driven by a 900 horsepower electric motor.

FIGURE 2

PROCESS FLOW DIAGRAM



Storage Bin

Shredded municipal solid waste is difficult to store. It conveys easily but once piled up, it tends to densify and stick together. A 2,000 ton conical, live bottom, Atlas storage bin was chosen to store the shredded waste. This device was originally developed for agricultural products but handles solid waste well. A similar storage bin has been used successfully at the St. Louis energy recovery project.

The shredded waste enters the top of the bin and forms a conical pile. A rotating drag line with buckets at the bottom of the pile undercuts the pile and drags the material to a conveyor under the floor of the bin. The storage bin effectively isolates the dumping, loading, and shredding operations from the downstream processes and acts as a buffer to absorb minor process interruptions while firing continuously into the pyrolytic reactor (kiln).

Reactor Feed

The shredded waste is conveyed from the storage bin at a constant rate and fed into the reactor by twin hydraulic rams.

Pyrolytic Reactor

The pyrolysis reaction takes place in a refractory lined horizontal rotary kiln* having a throughput of 42 tons per hour.

The refractory lining, a concrete-like material, keeps the heat of reaction within the kiln and prevents erosion of the kiln shell. The heat required to accomplish the pyrolysis reaction is provided by both the partial burning of the solid waste and a supplemental fuel. A portion of the solid waste is combusted using 40 percent of the air theoretically required for complete combustion. Number 2 heating oil, at the rate of 7.1 gallons per input ton of waste, provides the remainder of the required heat. The fuel oil burner is located in the discharge end of the kiln. Pyrolysis gases move counter-current to the waste and exit the kiln at the feed end. The gas temperature is controlled to 1200F and the residue is kept below 2000F to prevent slagging. If the temperature of the residue is above 2000F, the glass will melt and stick to the metal, and all the residue would become one dense mass that would require crushing for further processing.

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* The kiln is 19 feet in diameter, 100 feet long and rotates at approximately 2 revolutions per minute.

Energy Recovery

The pyrolytic gases (Table 3) leave the kiln and go to the afterburner (gas purifier) where they are combusted with additional air. The gases, which have a heat content of about 120 British Thermal Units (BTU) per dry standard cubic foot, are allowed to burn to completion.

TABLE 3

PYROLYTIC GASES
(Percent by Volume, Dry Basis)

Nitrogen	69.3
Carbon Dioxide	11.4
Carbon Monoxide	6.6
Hydrogen	6.6
Methane	2.8
Ethylene	1.7
Oxygen	1.6

The combustion temperature is in the range of 1400F to assure efficient and complete burning. The heat released from burning the gases is directed into two waste heat boilers (heat exchangers), operating in parallel, which generate 200,000 pounds of steam per hour.

Exhaust Gas System

After exiting the boilers, the waste gases are cleaned of particulate matter in a water spray unit called a scrubber. The scrubbed gases then pass through an induced draft fan which provides the force for drawing the gases through the entire system. The gases, saturated with moisture, are passed through a dehumidifier where they are cooled (by ambient air). The water thus removed is recycled. The dehumidified, cooled gases are then combined with ambient air that has been heated and discharged to the atmosphere. This process suppresses the formation of steam plumes.

Solids are removed from the scrubber water system by diverting part of the recirculated water to a thickener, a tank were the solid material is allowed to settle out. Flocculent (chemicals that cause the suspended solids to lump together and settle quickly) is added in the thickener to aid in solids removal. The clarified thickener overflow is recycled to the scrubber while the underflow stream containing the settled solids is used as coolant in the residue quench tank. The cooler-scrubber water system is a closed loop requiring very

little make up water. The plant is designed to allow the afterburner gases to bypass either or both of the boilers and enter the scrubbing tower directly. This feature allows the plant to dispose of solid waste during boiler outages, or at times when less than design amounts of steam are required.

Materials Recovery

The hot residue is discharged from the kiln into a water filled quench tank. A conveyor dewaters and elevates the wet residue from the quench tank into a flotation separator. The light material, carbon char, floats off as a slurry and is thickened and filtered to remove the water. Clarified water and filtrate are recirculated within the plant's closed-loop water system. The wet (50 percent moisture) carbon char will be disposed of in a land disposal site until firm markets for the material are developed. (See Product Description and Marketing section.) The remaining heavy material (sink fraction) from the bottom of the flotation separator is conveyed to a magnetic separator where the ferrous metals are removed. The ferrous (iron) material is deposited into containers for shipment to a scrap user. The balance of the heavy material is about 65 percent glass. This material, called glassy aggregate, passes through screening equipment with 0.5 inch openings and is then stored on-site. This glassy material will be used as aggregate in the bituminous concrete products (often called "glassphalt") used to pave the City's streets.

Redundancy

Waste generation will continue whether the processing plant is able to operate or not; therefore, a standby disposal system or redundant processing line is required. For short periods of system down-time, the three day storage capacity of the dump pit and storage bin will be put to use. The plant is designed with a quick repair capability. There are many installed spares, and changeover will take minimum time. All equipment is designed to be repairable or rebuildable within three to five days. Even the kiln's refractory lining could be replaced within this short down-time. The two waste shredders are operated in parallel, each with the capacity of 50 tons per hour. The shredders operate independently. Either could feed the plant, at a lesser throughput or longer shift hours.

Energy Balance

As with any energy system, the energy balance sheet is of prime importance in determining overall system efficiency and effectiveness. A solid waste disposal system can be either energy

consumptive, neutral, or energy producing, depending on system design and technology. In choosing pyrolysis as a technology, a net energy gain was expected.

The data in Table 4 reflect the energy inputs and outputs of the system, and also show the total material balances of the system. In making the calculations, the following assumptions were used:

a. Electrical power required to process one ton of waste was determined by using quoted electrical equipment ratings, by estimating how long each piece of equipment would have to operate to process one ton of waste, then by converting to BTU's assuming 30 percent conversion efficiency from fossil fuel.

b. Number 2 fuel oil needed to pyrolyze the waste is fed at 7.1 gal. per ton.

c. The waste has 4600 BTU per pound of heat value.

d. Fuel required by the two bulldozers is 16 gal. per hour.

e. Fuel used by other internal combustion engine vehicles is 10 gal. per day (crane, loader, etc.).

The calculations are only approximate and are based on scale-up factors and engineering estimates. The results show a 51 percent plant efficiency (output energy divided by input energy). A 51 percent efficiency is relatively good compared to other utility plants (fossil fuel steam or electric, nuclear, water wall incinerator, etc.). The point of this discussion is to emphasize that solid waste can replace other expensive or depletable energy sources in an efficient manner. It would require 670 pounds of coal or 46 gallons of oil to produce the same amount of steam that this plant will produce from one ton of solid waste. No attempt was made to compute the energy savings realized by recycling the recovered iron or aggregate.

PRODUCT DESCRIPTION AND MARKETING

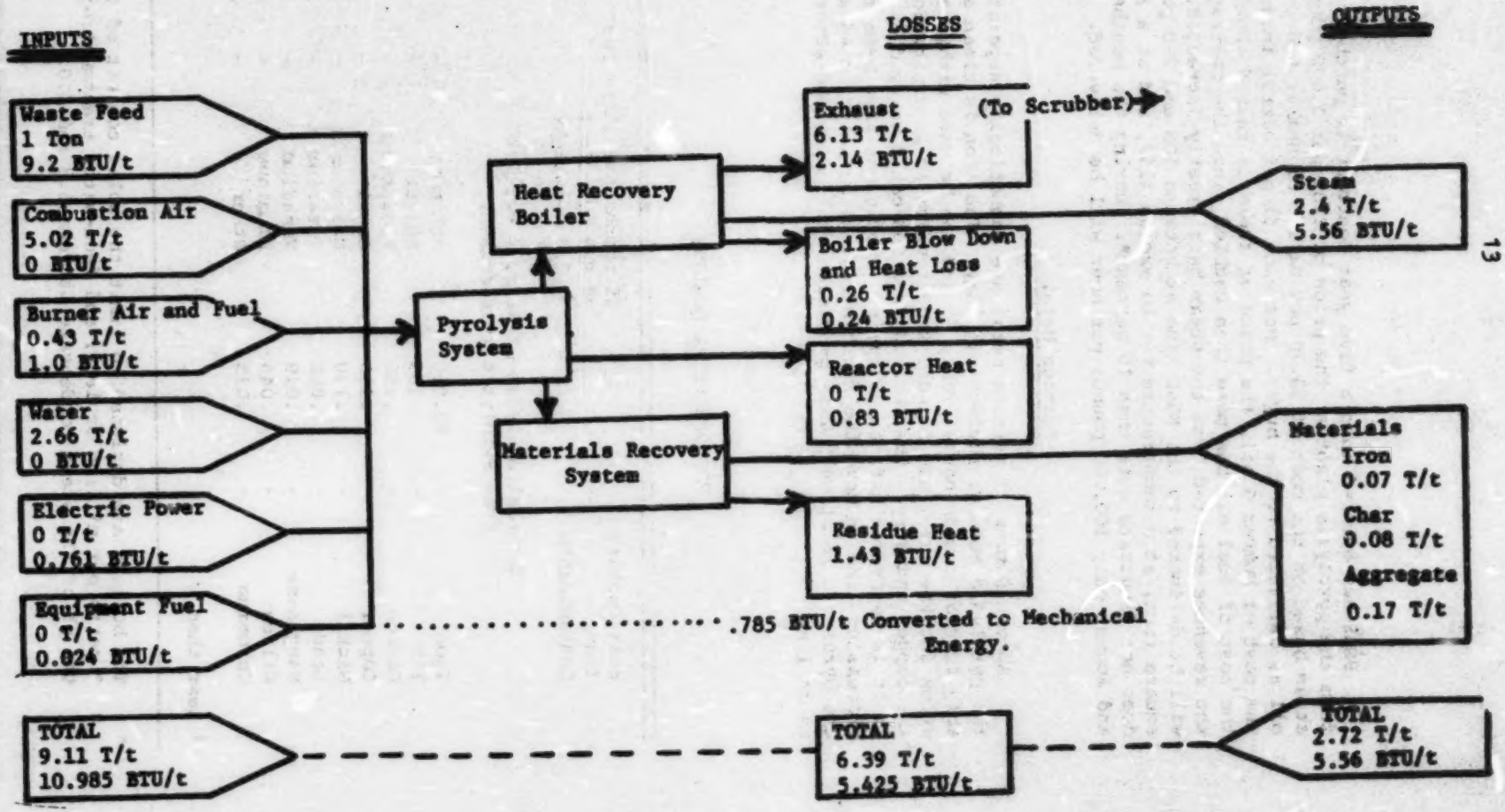
Steam

The transportation of steam over great distances is uneconomical. Thus, a market for steam must be close by. Such a market exists in Baltimore. Steam generated at the rate of 200,000 pounds per hour is transported in a 4,500 ft. steam main to an existing Baltimore Gas and Electric Company (BG&E) steam distribution line. It will be used in district (downtown area buildings) heating and cooling.

TABLE 4

ENERGY AND MATERIAL BALANCES

(T/t - Ton of Material Per Ton of Solid Waste Input)
(BTU/t - Million BTU's Per Input Ton)



BG&E has entered into a five year contract to purchase the steam from the pyrolysis plant at the price of $.81 per 1,000 pounds of steam based on the cost of $3.70 per barrel of Number 6 heavy fuel oil as delivered to the buyer. For each $1 per barrel increase in the cost of Number 6 oil, the price of steam is raised about $.22. As the cost of fuel oil has more than doubled since the contract was signed, the revenues expected from the steam have greatly increased. The steam will be delivered to the BG&E line at between 100 and 260 pounds per square inch, at a temperature not to exceed 415F, and at a rate that does not fluctuate more than 15 percent*. During the months of July and August only 100,000 pounds per hour will be delivered.

Ferrous Metal

About 70 tons of ferrous metal are magnetically separated from the pyrolysis reactor residue each day. The iron is clean and reasonably free of contaminants (Table 5) and can be used either as melting stock for the steel and foundry industry, or as precipitation iron in the copper industry. The ferrous fraction could be used by a detinner if it is recovered before pyrolysis. Provisions have been made in the processing line to move the ferrous separation point in advance of the pyrolytic reaction. This provision will be tested after the plant is on line.

TABLE 5

FERROUS METAL QUALITY

Bulk Density	35 pounds per cubic foot
Iron	98.85% by weight
Contaminants	1.15% by weight

Chemical Analysis of Ferrous Metal from Pyrolysis (Percentage)

Iron	-	98.850	Antimony	-	.020*
Tin	-	.153	Sulfur	-	.016
Carbon	-	.150	Phosphorus	-	.015
Copper	-	.150	Cobalt	-	.010*
Nickel	-	.140	Molybdenum	-	.010*
Lead	-	.088	Titanium	-	.010*
Manganese	-	.048	Vanadium	-	.010*
Silica	-	.045	Aluminum	-	.001*
Chromium	-	.035	Other	-	.249

* Less than

* The boilers are designed to limit the solid content of the steam to 3 parts per million or less; and feed-water treatment will maintain the ph of the steam condensate between 6.8 and 9.0.

The market available for the ferrous fraction will determine the process that must be used in removing the iron from the waste stream. There are three basic markets for the iron in solid waste. They are: the copper precipitation industry, the detinning industry, and the steel industry. Each one of these markets require different characteristics of the iron fraction. For instance, the detinning industry requires tin cans that are not balled up or crushed, but rather shredded or open so that a large surface is available for the detinning chemicals to work properly. The copper industry also needs an open can but that has been detinned by some process, either thermal or chemical. On the other hand, the steel industry wants a tin and copper free iron that is dense (crushed, shredded, or balled).

The Metal Cleaning and Processing Company has contracted to buy the post-pyrolysis ferrous fraction for 38.6 percent of the weekly quoted price on Number 2 Bundles as listed on the Philadelphia Market in Iron Age Magazine. This iron will be used for steel mill feed stock.

Glassy Aggregate

A glassy residue is recovered from the sink fraction of the flotation unit. This material is relatively metal free (Table 6) and will be used in road construction. Baltimore tested this material (obtained from the pilot plant) as an aggregate in bituminous paving mixtures (asphalt), in both a laboratory and on a section of a street in the city. The results were promising and the City is planning full scale street use once the material is available. City street construction specifications will be revised to allow or to require the use of this material as aggregate in binder course mixes for City streets. Is is anticipated that the glassy aggregate will have a value of $2 per ton at the plant site.

TABLE 6

GLASSY AGGREGATE ANALYSIS

Bulk Density	150 pounds per cubic foot
Composition:	Percent
Glass	65
Rock & Misc.	28
Ferrous Metal	3
Non-Ferrous Metal	2
Carbon	2

Carbon Char

The last output of the plant is a carbon char residue. It is the float fraction of the flotation unit and is generated at the rate of 80 tons per day. The properties of this materials are shown in Table 7.

TABLE 7

CARBON CHAR ANALYSIS

Bulk Density	20-50 pounds per cubic foot
Moisture Content	50% per pound
Heating Value, Dry Basis	7,000 BTU per pound

Analysis, Dry Basis

Component	Percent
Carbon	50.0
Ash and Glass	45.8
Volatiles	4.0
Sulfur	0.2

Extract Analysis

Component	Percent or Parts Per Million (PPM)
Sodium	over 30%
Calcium	0.1-1.0%
Copper	0.03-0.3%
Magnesium	0.03-0.3%
Potassium	0.03-0.3%
Boron	0.01-0.1%
Strontium	0.001-0.1%
Iron	0.001%*
Molybdenum	0.001%*
Silicon	0.001%*
Phosphorus	25 ppm*
Chromium	10 ppm*
Lead	10 ppm*
Tin	10 ppm*
Vanadium	5 ppm*
Zinc	5 ppm*
Aluminum	1 ppm*
Cadium	1 ppm*
Manganese	1 ppm*
Silver	1 ppm*
Titanium	1 ppm*

* Less than

Two possible uses for the char are:

a. As a substitute for commercial activated carbon for waste water treatment plants. Laboratory experiments have substantiated the absorption characteristic of carbon char, and further research on carbon slurry absorption is scheduled.

b. As a soil conditioner along with dried and digested sewage sludge. This use will be tested in Baltimore. The char could be mixed with the City's sludge, dried, and given to the public at no charge.

However, until a good market for the char is developed, it will be disposed of in a landfill.

ECONOMICS

The economics of the pyrolysis plant is only an estimate at this stage of the project. In addition, it should be noted that the data presented below are very site specific. It would not be advisable to assume that these figures are automatically applicable to other locations without a prior study of pertinent factors such as site costs, labor and material costs, product marketability, plant size, etc. No attempt has been made to normalize these figures to make them applicable to other areas of the country except for the method of capital amortization. Since the Baltimore situation is unique because an EPA Grant and an MES loan are applied to the capital cost of the plant, Baltimore's actual amortization costs have not been presented. Instead, a typical 20 year, 6 percent municipal bond was used to determine capital cost figures.

Table 8 presents the capital and operating cost and revenues of the plant. Plant throughput, based on 85 percent availability, will be 310,000 tons per year, and all costs and revenues have been converted to dollars per ton. A comparison is shown between anticipated economics of January 1974 and those of February 1974 to illustrate the effect of inflation. With the escalating cost of fossil fuel, an energy recovery plant has a good possibility of operating at a break even point, and could make a profit for a city.

TABLE 8

ECONOMICS

($ Per Throughput Ton)

		January 1973		February 1974
Amortization*		$4.34		$5.55
Operating Costs				
Fuel	$ .89		$ 2.20	
Electricity	1.06		1.50	
Manpower	1.02		1.10	
Water and Chemicals	.31		.30	
Maintenance	1.84		1.90	
Miscellaneous	.42		.40	
Char Removal	.18		.20	
Total		$5.72		$7.60
Total Expenses		$10.06		$13.15
Revenues				
Steam**	$3.89		$11.18	
Iron	.44		1.55	
Glassy Aggregate	.34		.40	
Total Revenues		$4.67		$13.13
Net Operating Cost		$5.39		$ .02

* Approximated Plant Cost:

January, 1973	$16 million
February, 1974	$20 million

** Steam Revenues:

January, 1973	$3.70 per barrel fuel oil
February, 1974	$10.63 per barrel fuel oil

ENVIRONMENTAL CONSIDERATIONS

Environmental Advantage

No pyrolysis system for solid waste has as yet operated at full scale. One of the objectives of the resource recovery grant is to demonstrate whether this system can recover the energy and material resources in municipal solid waste without polluting the environment. The success of the plant will:

1. Allow BG&E Co. to save 15 million gallons of oil annually.
2. Permit the City to dispose of much of its solid waste with lower air emissions than is presently possible.
3. Cause steam to be produced with lower emissions than can be produced from existing boilers.
4. Enable industry to use recovered materials instead of depletable virgin materials in new products, to conserve resources, and save energy.

Air Emissions

Once the plant is operational, Baltimore will be able to close down one existing incinerator that does not meet clean air standards. Air emissions from the pyrolysis plant will meet the Federal particulate emission standard of .08 grains per standard cubic foot of dry flue gas corrected to 12 percent CO_2, and the Maryland code of .03 grains per standard cubic foot. As there is very little sulfur in solid waste, the sulfur dioxide emissions from the plant are correspondingly low, in the under 100 parts per million range. Nitrogen oxide (NO_x) production in the plant is also kept at a low level by combusting the pyrolysis gases at a low temperature. The NO_x emissions are in the range of less than 50 parts per million. Unburned hydrocarbons in the exhause are held to just a few parts per million of methane equivalent. The emission quality is guaranteed by the contractor. Moreover, the plant will be closely monitored, as a part of the EPA evaluation, to assure that all applicable local, state, and Federal point source and ambient air quality standards are met.

Water Effluent

All process water is recycled. However, occassionally recycled water will exceed needs and any excess water will be discharged into the sanitary sewer at a maximum flow of 75 gallons per minute. Any water so discharged will be treated at Baltimore's Back River Plant and will not significantly change the influent characteristics of the treatment plant. The Back River Plant employs both primary and secondary treatment processes.

Land Pollution

The only plant output that may be disposed of on land is the carbon char. If use of this material is not possible, then it will have to be landfilled. The char contains about one percent (Table 7) of water soluble material and disposal will have to be engineered to prevent the char leachate from entering the groundwater system.

Noise

Hammermilling solid waste is a noisy operation. The shredders are located above ground in sound-proofed structures. All other equipment that could cause noise pollution is protected. All applicable noise regulations will be met, and ambient noise at the plant boundaries will be within standards for this industrially zoned site.

Environmental Summary

There will be no significant adverse environmental effect from the operation of this solid waste conversion plant. On the contrary, if the process proves successful, the City can reduce total pollution associated with present practices of landfilling, incineration, use of iron ore in steelmaking, and use of fossil fuels to generate steam.

GUARANTEE

Monsanto is responsible for the complete design, construction and start-up of the plant, all at a fixed price. The contract calls for Monsanto to turn over to Baltimore a completely operational "turnkey" facility. Additionally, the contract provides for up to $4 million in performance penalities if the plant fails to meet any of the following standards:

1. Air emissions will meet existing Federal, State, and local air pollution regulations.

2. Plant capacity will average a minimum of 85 percent of design capacity for an identified 60 day period.

3. Putrescible content of residue will be less than 0.2 percent.

PROJECT EVALUATION

The pyrolysis plant will be technically, economically, and environmentally evaluated by an independent contractor hired by EPA during the first year of operation, and the results will be disseminated to the public. Each processing step will be evaluated to determine its ability to meet the original design requirements, its operation and maintenance costs, its economic balance, its energy balance, and so forth. Plant effluents and products will be analyzed to make sure they meet design specifications and environmental acceptability.

An interim report will be published in the Fall of 1975. A final report will be published in late 1976.

Once operational, the plant will be open to the general public. For information about visiting hours and tour arrangements, contact Mr. Elliot Zulver, Project Officer, Bureau of Utility Operations, 900 Municipal Building, Baltimore, Maryland 21202.

QUESTIONS AND ANSWERS

1-Q: Our city has a separate newspaper collection. How would that affect a pyrolysis plant?

A: Removing newspapers from the waste stream for recycling is an environmentally and economically sound technique in resource recovery and is a recommended approach to be used in conjunction with an energy recovery plant. Removing the newsprint prior to pyrolysis will reduce the total tonnage and BTU content of the waste, but generally only by a small percentage. (See Recommended Reading).

2-Q: What if there is no market for steam in our city? Can we still use a gaseous pyrolysis system?

A: The lack of a market for steam has severely limited solid-waste-to-steam-projects. However, provisions in the design of the Baltimore project have alleviated this constraint. Monsanto feels that the pyrolysis gas can be cleaned and piped a short distance to an industrial or utility boiler and burned along with the normally used fossil fuel. Another option proposed by Monsanto is to use the steam to generate electricity on site.

3-Q: What would happen to a Baltimore-type system if source reduction measures are implemented, like banning the throwaway beverage container?

A: If throwaway beverage containers are eliminated from the input feed of this plant, there would be a small reduction in the non-combustible fraction of the waste. The ferrous fraction would probably be cut in half, and the volume of glassy aggregate would be correspondingly reduced, but the overall economics of the plant would still be viable. Revenue would be reduced, but as energy production is the primary money-maker, the reduction would not be appreciable. The energy savings from eliminating throwaways would far overshadow the slight drop in revenue. Although, the energy savings may not directly affect the City, the loss of revenues would. If many source reduction measures were adopted, like reduction of packaging waste, the 1,000 ton per day plant would have to draw waste from a larger population base to generate the design throughput.

4-Q: If new resource recovery technology is developed in the next few years, won't Baltimore have an obsolete plant?

A: In our technological society, things become obsolete quickly; however, they remain useable. The Baltimore plant has a 15 to 20 year useful life. After that time, if new and better technology is available, it will probably be used. In the meantime, we must move ahead with the best available technology, now.

5-Q: We have about five years of life remaining in our landfill. Why should we worry about resource recovery now?

A: You should be planning now. The lead time on a resource recovery facility is from three to five years. Make decisions now: plan for alternate disposal methods before you become buried in your own waste.

RECOMMENDED READING

The following publications are available from:

Energy Recovery Program
Resource Recovery Division (AW-563)
Office of Solid Waste Management Programs
U. S. Environmental Protection Agency
Washington, D. C. 20460

1. Energy Conservation Through Improved Solid Waste Management by Robert A. Lowe, with appendices by Michael Loube and Frank A. Smith.

2. Energy Recovery from Waste by Robert A. Lowe.

3. Markets and Technology for Energy Recovery from Solid Waste by Steven J. Levy.

4. Pyrolysis by Steven J. Levy.

5. List of Pyrolysis Companies by Robert Holloway.

6. Effect of Removing Paper on the Energy Value of Solid Waste by Robert Holloway.

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